appear to have acted wisely in asking Mr. Philip Magnus, who has directed the work of the Institute up to the present time with so much ability, and whose exceptional experience of Continental technical schools renders him particularly fitting for such a position—to occupy this post, pending the completion of the Central Institution, and to carry into effect the general scheme of instruction indicated in the programme.

In the day school of the Finsbury College, pupils from middle class and higher elementary schools will have the opportunity of continuing their studies, and of preparing, at the same time, for the particular branch of industry in which they purpose to be engaged.

Such a school is a technical school in the true sense of the word, for it gives the pupil the best training he can receive for his future occupation.

The instruction is not limited to the application of one branch of science only; the future electrician is taught chemistry and mechanics, the chemist is taught mechanics and physics, the mechanician is taught physics and chemistry, and, what is almost equally important, all are taught drawing, French, German, and the manipulation of tools in the workshops.

The evening school is intended for those who are already engaged in practical work, and in this department of the College noteworthy changes have been introduced, with a view of adapting the teaching to the special requirements of artisans. To the courses of Applied Physics and Chemistry originally provided for, courses of Mechanical Engineering have been added; but besides these courses, which are adapted to the higher class of artisans, a complete syllabus of instruction has been added to the programme, suited to the requirements of the special industry of the district of Finsbury, viz. cabinet-making. To provide a systematic course of instruction for cabinet-makers it was necessary to add to the other departments of the College, a Department of Applied Art; and in order to secure a good number of students to start with, the Council affiliated to the College the City School of Art, one of the oldest art schools of the country, and appointed Mr. Brophy as head master.

Moreover, to satisfy the demand of workmen engaged in numerous small industries, the Council have arranged courses of instruction, on a more systematic basis than has been previously attempted in this country, for carpenters, joiners, metal-plate workers, bricklayers, &c., thereby supplying that popular element in the instruction provided by the City Guilds, which at first seemed likely to be wanting in their scheme of technical education.

By undertaking to admit apprentices to the evening classes at half the fees, which are small enough, charged to ordinary workmen, those who have had the direction of the work of the Institute have shown a just appreciation of the importance of encouraging apprentices of fifteen to twenty to follow the evening courses of instruction; for there will be far less difficulty in inducing youths, during their apprenticeship, to attend regular systematically-arranged lessons, covering a period of two or three years, than is generally found in the case of adult workmen.

Indeed, it is in the arrangement of systematised and progressive courses of instruction adapted to various industries and involving the application both of science and of art to the student's occupation, as well as in the practical methods of instruction adopted, that the Technical College, Finsbury, is differentiated from other science schools.

The programme of studies now before us is a publication that can hardly fail to prove useful to all persons who are interested in the establishment of technical schools, and shows unmistakably that the Council of the Institute and their advisers are fully conscious of the difficulties that beset the problem of technical education, and may be trusted to deal judiciously with them in the schools established under their direction.

The fittings of the new College, which are most complete and admirably adapted for practical teaching, have been designed and executed under the direction of Professors Armstrong, Ayrton, and Perry.

ON THE GRADUATION OF GALVANOMETERS FOR THE MEASUREMENT OF CURRENTS AND POTENTIALS IN ABSOLUTE MEASURE[1]

III.

THE determination of H and the measurement of a current in absolute units, can be effected simultaneously by the method devised by Kohlrausch, and described in the *Philosophical Magazine*, vol. xxxix. 1870. This method consists essentially in sending the current to be measured through two coils, of which all the constants are accurately known. One of these is the coil of a standard galvanometer, the other is a coil hung by a bifilar suspension, the wires of which convey the current into the coil. The latter coil rests in equilibrium when no current is passing through it, with its plane in the magnetic meridian. When a current is sent through it, it is acted on by a couple due to electro-magnetic action between the current and the horizontal component of the earth's force, which tends to set it with its plane at right angles to the magnetic meridian; and this couple is resisted by the action of the bifilar. The coil comes to rest, making a certain angle with the magnetic meridian, and as the couple exerted by the bifilar suspension for any angle is supposed to have been determined by experiment, a relation between the value of H and the value of the current is obtained. But, as the same current is sent through the coil of the standard galvanometer, the observed deflection of the needle of that instrument gives another relation between H and C. From the two equations expressing these relations the values of H and C can be found. Full details of the construction of Kohlrausch's apparatus and of the calculation of its constants will be found in the paper above referred to.

In this method it is assumed that the value of H is the same at both instruments, an assumption which for rooms not specially constructed for magnetic experiments cannot safely be made. An instrument which is not liable to this objection has been suggested by Sir William Thomson. A short account of this instrument and its theory will be found in Maxwell's "Electricity and Magnetism," vol. ii. p. 328.

In the application of what has gone before to the graduation of galvanometers, we shall have to deal with the quantities resistance and potential, and in our calculations to measure potentials in volts, resistances in ohms, and currents in amperes. A full explanation of the terms resistance and potential would require a treatise on electricity, but perhaps a very short explanation of what is meant by a volt, by an ohm, and by an ampere may not be here out of place.

Two conductors are at different potentials when, on their being put in contact, electricity passes from one to the other. The difference of potential between them will be made manifest if one of them be connected with an electrically insulated plate which forms one of the scales of a delicate balance, and the other with a second insulated plate parallel to, and at a very small distance from the first plate. If the conductors be at different potentials the plates will attract one another, and the force of attraction may be weighed by means of the balance. With certain arrangements to ensure accuracy, a balance may be constructed by means of which the difference of potentials between two conductors can be measured. Such an instrument has been made by Sir William Thomson, and called by him an Absolute Electrometer.

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[1] Continued from p. 108.

It is found experimentally by measuring with a delicate electrometer that, between any two cross-sections A and B of a homogeneous wire, in which a uniform current of electricity is kept flowing by any means, there exists a difference of potentials, and that if the wire be of uniform section throughout, the difference of potentials is in direct proportion to the length of wire between the cross-sections. It is found further that if the difference of potentials between A and B is kept constant, and the length of wire between them is altered, the strength of the current varies inversely as the length of the wire. The strength of the current is thus diminished when the length of the wire is increased, and hence the wire is said to oppose *resistance* to the current; and the resistance between any two cross-sections is proportional to the length of wire connecting them. If the length of wire and the difference of potentials between A and B be kept the same, while the cross-sectional area of the wire is increased or diminished, the current is increased or diminished in the same ratio; and therefore the resistance of a wire is said to be inversely as its cross-sectional area. Again, if for any particular wire, measurements of the current strength in it be made for various measured differences of potentials between its two ends, the current strengths are found to be in simple proportion to the differences of potential so long as there is no sensible heating of the wire. Hence we have the law, due to Ohm, which connects the current C flowing in a wire of resistance R, between the two ends of which a difference of potential V is maintained,

$$C = \frac{V}{R} \quad \cdots\cdots \quad (14)$$

In this equation the units in which any one of the three quantities is expressed depend on those chosen for the other two. We have defined unit current, and have seen how to measure currents in absolute units; and we have now to show how the absolute units of V and R are to be defined, and from them and the absolute unit of current to derive the practical units—volt, ampere, coulomb, and ohm.

We shall define the absolute units of potential and resistance by a reference to the action of a very simple but ideal magneto-electric machine, of which, however, the modern dynamo is merely a practical realisation. First of all let us imagine a uniform magnetic field of unit intensity. The lines of force in that field are everywhere parallel to one another: to fix the ideas let them be vertical. Now imagine two straight horizontal metallic rails running parallel to one another, and connected together by a sliding bar, which can be carried along with its two ends in contact with them. Also let the rails be connected by means of a wire so that a complete conducting circuit is formed. Suppose the rails, slider, and wire to be all made of the same material, and the length and cross-sectional area of the wire to be such that its resistance is very great in comparison with that of the rest of the circuit, so that, when the slider is moved with any given velocity, the resistance in the circuit remains practically constant. When the slider is moved along the rails it cuts across the lines of force, and so long as it moves with uniform velocity a constant difference of potentials is maintained between its two ends, and a uniform current flows in the wire from the rail which is at the higher potential to that which is at the lower. If the direction of the lines of force be the same as the direction of the vertical component of the earth's magnetic force in the northern hemisphere, so that a blue pole placed in the field would be moved upwards, and if the rails run south and north, the current when the slider is moved northwards will flow from the east rail to the west through the slider, and from the west rail to the east through the wire If the velocity of the slider be increased the difference of potentials between the rails, or, as it is otherwise called, the electromotive force producing the current, is increased in the same ratio; and therefore by Ohm's law so also is the current. Generally for a slider arranged as we have imagined, and made to move across the lines of force of a magnetic field, the difference of potentials produced would be directly as the field intensity, as the length of the slider, and as the velocity with which the slider cuts across the lines of force. The difference of potentials produced therefore varies as the product of these three quantities; and when each of these is unity, the difference of potentials is taken as unity also. We may write therefore $V = I L v$, where I is the field intensity, L the length of the slider, and v its velocity. Hence if the intensity of the field we have imagined be 1 c.g.s. unit, the distance between the rails 1 cm., and the velocity of the slider 1 cm. per second, the difference of potentials produced will be 1 c.g.s. unit.

This difference of potentials is so small as to be inconvenient for use as a practical unit, and instead of it the difference of potentials which would be produced if, everything else remaining the same, the slider had a velocity of 100,000,000 cms. per second, is taken as the practical unit of electromotive force, and is called one *volt*. It is a little less than the difference of potentials which exists between the two insulated poles of a Daniell's cell.

We have imagined the rails to be connected by a wire of very great resistance in comparison with that of the rest of the circuit, and have supposed the length of this wire to have remained constant. But from what we have seen above, the effect of increasing the length of the wire, the speed of the slider remaining the same, would be to diminish the current in the ratio in which the resistance is increased, and a correspondingly greater speed of the slider would be necessary to maintain the current at the same strength. We may therefore take the speed of the slider as measuring the resistance of the wire. Now suppose that when the slider 1 cm. long was moving at the rate of 1 cm. per second, the current in the wire was 1 c.g.s. unit; the resistance of the wire was then 1 c.g.s. unit of resistance. Unit resistance therefore corresponds to a velocity of 1 cm. per second. This resistance, however, is too small to be practically useful, and a resistance 1,000,000,000 times as great, that is, the resistance of a wire, to maintain 1 c.g.s. unit of current in which it would be necessary that the slider should move with a velocity of 1,000,000,000 cms. (approximately the length of a quadrant of the earth from the equator to either pole) per second, is taken as the practical unit of resistance, and called one *ohm*.

In reducing the numerical expressions of physical quantities from a system involving one set of fundamental units to a system involving another set, as for instance from the British foot-grain-second system, formerly in use for the expression of magnetic quantities, to the c.g.s. system, it is necessary to determine, according to the theory first given by Fourier, and extended to electrical and magnetic quantities by Maxwell, for each a certain reducing factor, by substituting in the formula, which states the relation of the fundamental units to one another in the expression of the quantity, the value of the units we are reducing from in terms of those we are reducing to. For example, in reducing a velocity say from miles per hour, to centimetres per second, we have to multiply the number expressing the velocity in the former units by the number of centimetres in a mile, and divide the result by the number of seconds in an hour; that is, we have to multiply by the ratio of the number of centimetres in a mile to the number of seconds in an hour. The multiplier therefore, or *change-ratio* as it has been called by Professor James Thomson, is for velocity simply the number of the new units of velocity equivalent to one of the old units, and may be expressed by the formula $\frac{L}{T}$, where L is the number of new units of length contained in one of the old, and T is the corresponding number for the unit of time. In the same way the change-ratio for rate of change of velocity or acceleration is $\frac{L}{T}$; and the change-ratio of any other physical quantity may be found by determining from its definition the manner in which its unit involves the fundamental units of mass, length and time. Now the theory of the change-ratios of electrical and magnetic quantities, in the electro-magnetic system of units, shows that the change-ratio for resistance is the same as that for velocity; that in fact a resistance in electro-magnetic measure is expressible as a velocity; and hence we may with propriety speak of a resistance of one ohm as a velocity of 10^9 centimetres per second.

It is obvious from equation (14) that if V and R, each initially one unit, be increased in the same ratio, C will remain one unit of current; but that of V be, for example, 10^8 c.g.s. units of potential, or one volt, and R be a resistance of 10^9 cms. per second, or one ohm, C will be one-tenth of one c.g.s. unit of current. A current of this strength—that is, the current flowing in a wire of resistance one ohm, between the two ends of which a difference of potentials of one volt is maintained,—has been adopted as the practical unit of current and called one *ampere*. Hence it is to be remembered one ampere is one-tenth of one c.g.s. unit of current.

The amount of electricity conveyed in one second by a current of one ampere is called one *coulomb*. This unit although not quite so frequently required as the others, is very useful, as, for instance, for expressing the quantities of electricity which a secondary cell is capable of yielding in various circumstances. For example, in comparing different cells with one another their capacities, or the total quantities of electricity they are capable of yielding when fully charged, are very conveniently reckoned in coulombs per square centimetre of the area across which the electolytic action in each takes place.

The magneto-electric machine we have imagined gives us a very simple proof of the relation between the work done in maintaining a current, the strength of the current, and the electromotive force producing it. By the definitions given above of a magnetic pole and a magnetic field, a unit pole must produce at unit distance from itself a magnetic field of unit intensity. Again, unit current is defined as that current which flowing in a wire of unit length, bent into an arc of a circle of unit radius, acts on a unit magnetic pole at the centre of the circle with unit force. Hence, as the reaction of the pole on the current must be equal to the action of the current on the pole, this wire carrying the current is acted on by unit force tending to move it in the opposite direction to that in which the pole is moved, and it plainly does not matter which we suppose held fixed and which moved. Therefore a conductor in a magnetic field, and carrying a unit current which flows at right angles to the lines of force, is acted on by a force tending to move it in a direction at right angles to its length, and the magnitude of this force for unit length of conductor, and unit field, is by the definition of unit current equal to unity.

Applying this to our slider in which we may suppose a current of strength C to be kept flowing, say, from a battery in the circuit, let L be the length of the slider, v its velocity, and I the intensity of the field; we have for the force on the moving conductor the value ILC. Hence the rate at which work is done by the electro-magnetic action between the current and the field is $ILC\frac{dx}{dt}$ or $ILCv$, and this must be equal to the rate at which work is done in generating by motion of the slider a current of strength C. But as we have seen above ILv is the electromotive force produced by the motion of the slider. Calling this now E, the symbol usually employed to denote electromotive force, we have EC as the rate of working, that is, the rate at which electrical energy is given out in the circuit.

By Ohm's law this value for the rate of working may be put into either of the two other forms, namely: $\frac{E^2}{R}$, or C^2R. In the latter of these forms the law was discovered by Joule, who measured the amount of heat generated in wires of different resistances by currents flowing through them. This law holds for every electric circuit whether of dynamo, battery, or thermoelectric arrangement.

We have, in what has gone before, supposed the slider to have no resistance comparable with the whole resistance in the circuit. If it has a resistance r, and R be the remainder of the resistance in circuit, the actual difference of potentials between its two ends will not be ILv or E, but $E\frac{R}{R+r}$. The rate per unit of time at which work is given out in the circuit is however still EC, of which the part $EC\frac{r}{R+r}$ is given out in the slider, and the remainder, $EC\frac{R}{R+r}$, in the remainder of the circuit. In short, if V be the actual difference of potentials, as measured by an electrometer, between two points in a metallic wire connecting the terminals of a battery or dynamo, and C be the current flowing in the wire, the rate at which energy is given out is VC, or if R be the resistance of the wire between the two points, C^2R.

One of the great advantages of the system of units of which I have given this brief sketch, is that it gives the value of the rate at which work is given out in the circuit, without its being necessary to introduce any coefficient such as would have been necessary if the units had been arbitrarily chosen. When the quantities are measured in c.g.s. units, the value of EC is given in terms of the centimeter-dyne or *erg*, the recognized dynamical unit of work. Results thus expressed may be reduced to *horse-power* by dividing by the number $7{\cdot}46 \times 10^9$; or if E is measured in volts, and C in amperes, EC may be reduced to horse-power by dividing by 746. Thus, if 90 volts be maintained between the terminals of a pair of incandescent lamps joined in series, and a current of 1·3 ampere flows through these lamps, the rate at which energy is given out in the lamps is approximately ·157 horse-power.

ANDREW GRAY

(*To be continued.*)

NATURAL SCIENCE IN THE OPEN COMPETITIVE EXAMINATIONS FOR CLERKSHIPS (CLASS I.) IN THE CIVIL SERVICE

THE Civil Service Commissioners have done much to encourage the thorough study of natural science in our Universities by the weight which they have assigned to it in the competitive examinations for first-class clerkships in the Government service. These posts are of sufficient value to attract young men of one or two-and-twenty, fresh from the University. It will be seen from the list of marks assigned to subjects, which we print below, that 1000 marks may be made in two branches of natural science, for instance, Zoology and Geology; whilst Greek and Roman language, literature, and history only stand for 1500. Hence a candidate who makes science his strong side and can do something in either English, classical, or foreign literary subjects, is by no means at a disadvantage.

We take this opportunity of prominently drawing attention to the encouragement thus given to the pursuit of natural science as a branch of culture.

The schoolboy who is excused from verse-composition and sent into the chemical laboratory, is distinctly recognised, and has a fair chance given to him by the Commissioners. So too the Oxford undergraduate who breaks with the wearisome iteration of Greek play and Latin